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Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

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Iseberg et al.

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[45] Date of Patent: Mar. 23, 1999

[54] **HIGH FIDELITY INSERT EARPHONES AND METHODS OF MAKING SAME**

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[73] Assignee: **Etymotic Research, Inc.**, Elk Grove Village, Ill.

[21] Appl. No.: **770,647**

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[63] Continuation of Ser. No. 597,940, Feb. 7, 1996, abandoned, which is a continuation of Ser. No. 430,698, Apr. 27, 1995, abandoned, which is a continuation of Ser. No. 880,244, May 8, 1992, abandoned.

[51] **Int. Cl.**[6] **H04R 25/00**

[52] **U.S. Cl.** **381/380**; 381/328; 181/130

[58] **Field of Search** 381/25, 23.1, 67, 381/68, 68.2, 68.4, 68.6, 68.7, 69, 154, 183, 187, 189, 205, 309, 327, 328, 325, 380, 322, 324, 382, 126, 133, 135, 149, 150; 181/129, 130, 131, 135; 379/430

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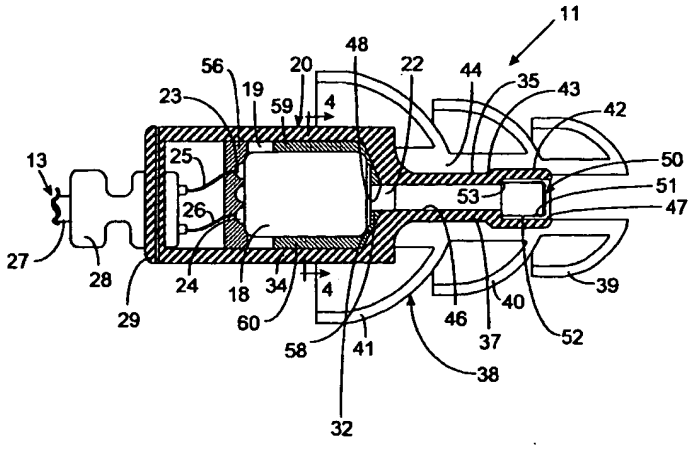
[57] **ABSTRACT**

An insert earphone is provided in which a piece of foam material is used to resiliently mount a receiver within a chamber portion of a one-piece plastic housing member. The receiver has an output port extending through a central aperture of the piece of foam material and into one end of a passage defined by a tubular portion of the housing member with a damper being disposed in the other end of the passage. The tubular portion is inserted into an ear tip or other coupling device and has an enlarged diameter end section to achieve a locking action. Two such insert earphones may be coupled through cables to a junction unit and filters are provided for enhancing the drive of the earphones at high frequencies, the filters being preferably mounted in the junction unit.

15 Claims, 5 Drawing Sheets



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HIGH FIDELITY INSERT EARPHONES AND METHODS OF MAKING SAME

This is a continuation of application Ser. No. 08/597,940, filed Feb. 7, 1996, now abandoned, which is a continuation of application Ser. 08/430,698, filed Apr. 27, 1995, now abandoned, which is a continuation of Ser. No. 07/880,244 filed May 8, 1992, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to earphones and methods of making the same to obtain earphones and earphone assemblies which reproduce sounds with very high fidelity and with minimum noise and which are suitable for use by the most discriminating listeners. The earphones and assemblies of the invention are very compact and light in weight, are highly reliable and are readily and economically manufacturable.

2. Background of the Prior Art

"Audiophile" earphones have been marketed for use by audiophiles or discriminating listeners interested in the highest possible sound reproduction. Such audiophile earphones have been ostensibly capable of effecting high fidelity sound reproduction although it has been recognized by many users as well as the makers of such earphones that they have left much to be desired with respect to fidelity of reproduction. It has apparently been assumed by such users and makers that deficiencies in quality of sound reproduction are an unavoidable result of the use of earphones.

In a separate audiometry art, earphones have also been developed and marketed in limited quantities for use in specialized audiometry applications to measure the responses of a patient's ear and having features for obtaining desired response characteristics, one disclosure being contained in the Killion U.S. Pat. No. 4, 763,753, issued Aug. 16, 1988. Another separate art, the hearing aid art, also contains many disclosures related to the achievement of improved response characteristics, including a paper entitled "SMOOTHING THE ITE RESPONSE: THE BF-1743 DAMPED COUPLING ASSEMBLY" by Mead C. Killion and William J. Murphy, first published in April 1981 and revised June 1982, by Industrial Research Products, Inc. Elk Grove Village, Ill. Such disclosures in the audiometry and hearing aid art relate to devices of relatively expensive construction which are designed for specialized applications and marketed in limited quantities. The applicability of the audiometry and hearing aid arts to the making of earphones for use in high fidelity sound reproduction has apparently gone unrecognized.

SUMMARY OF THE INVENTION

This invention was evolved after learning of the deficiencies of earphones marketed for use by audiophiles and with the general object of providing earphones which have improved high fidelity response characteristics and which are readily and economically manufacturable.

Important aspects of the invention relate to the recognition and discovery of problems with prior art arrangements and their causes and to an analysis of what is necessary to overcome such problems and otherwise provide improved earphones. It was discovered that one serious problem with audiophile earphones has been related to the failure to recognize the need to compensate for loss of external-ear resonance when using an earphone and the failure to provide

compensating acoustic characteristics between the ear canal of a user and the transducer or receiver used to develop an audio signal from an applied electrical signal. It was further discovered that features of a damped coupling assembly of the hearing aid disclosed in the aforementioned Killion and Murphy paper might be applied with advantage to the construction of an audiophile earphone. With a damped coupling assembly as disclosed in that paper, a damper is coupled through a tube to an output port of a receiver and is disposed within the tip of an earmold. The arrangement produces a frequency response which will compensate for the loss of external ear resonance and which is largely independent of the total length of the coupling between the receiver and the earmold tip.

In accordance with the invention, an audiophile insert earphone is provided which uses a damped coupling assembly similar to that disclosed in the above-mentioned Killion and Murphy paper and operative to provide compensation for the loss of external-ear resonance. In accordance with one important feature of the invention, a pair of such earphones are combined in a dual earphone assembly usable for stereophonic reproduction.

Additional important features of the invention relate to features of construction which facilitate manufacture of insert earphones and which at the same time achieve reproduction of sounds with very high fidelity and with a high degree of reliability. Certain of such features relate to the provision of a housing member which can be readily molded from plastic in one piece and which serves the functions of connecting to an outlet port of a receiver, supporting a damper and providing a sound passage. The housing member also serves to releasably connect to a coupling device such as an earmold or ear tip and it performs all of such functions with a high degree of accuracy and reliability. Others such features relate to the provision of a resilient support for the receiver to minimize the effects of vibrations and noise and to methods of making the earphone to facilitate manufacture at low cost.

Another feature relates to the combination of electrical filters with the earphone and its damped coupling assembly to achieve optimum overall results.

Still another feature relates to a construction to facilitate removal and replacement of a damper and to the provision of a tool for that purpose.

This invention contemplates other objects, features and advantages which will become more fully apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a high fidelity insert earphone assembly of the invention;

FIG. 2 is a cross-sectional view of one earphone of the assembly of FIG. 1, taken substantially along line 2—2 of FIG. 1;

FIG. 3 shows a piece of resilient material used in construction of the earphone of FIG. 1;

FIG. 4 is a cross-sectional view taken substantially along line 4—4 of FIG. 2;

FIG. 5 is a circuit diagram of a electrical filter unit of the assembly of FIG. 1; and

FIG. 6 is a side elevational view, partly in section, illustrating a device usable for removal of dampers of the earphones of the invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

In FIG. 1, reference numeral 10 generally designates an earphone assembly which is constructed in accordance with

the principles of this invention and which is suitable for use by an audiophile, for example. It will be understood, however, that a number of features of the invention are not limited to any particular use. Certain features may be used, for example, in the construction of hearing aids for use by persons having a hearing impairment.

The illustrated assembly **10** includes a pair of earphones **11** and **12** for insertion into the entrances of the ear canals of a user. A pair of cables **13** and **14** connect earphones **11** and **12** to a junction unit **15** and a common cable **16** connects the junction unit **15** to a plug connector **17** which may be connected to an output jack of a stereophonic amplifier, for example.

FIG. **2** is a cross-sectional view of the earphone **11**, the construction of the other earphone **12** being preferably identical to that of the earphone **11**. The earphone **11** comprises a receiver **18** which is mounted in a chamber portion **19** of a housing member **20**. The receiver **18** has an acoustic output port and has electrical input terminals **23** and **24** and is operative for generating an acoustic output signal at the output port **22** as a function of an electrical signal applied to the terminals **23** and **24**. The terminals **23** and **24** are connected through wires **25** and **26** to conductors of the cable **13** and an outer sheath **27** of the cable **13** is bonded to a strain relief member **28**. Member **28** is secured in an opening of an end cap **29** which is secured to one end of the housing member **20** to close one end of the chamber portion **19**.

The housing member **20** includes a wall **32** at an opposite end of the chamber portion **19** and an outer wall **34** of the chamber portion **19** which is in surrounding relation to the receiver **18** and which may preferably be of generally cylindrical form.

The housing member **20** further includes a tubular portion **35** which projects from the end wall **32** of the chamber portion of the housing member and which is inserted in an opening **37** of an acoustic coupling device **38** arranged to be inserted into the entrance of an ear canal of a user. As shown, the coupling device **38** is in the form of an eartip of a soft compliant material and has three outwardly projecting flange portions **39**, **40** and **41** which are of generally conical form and of progressively increasing diameters, arranged to conform to the inner surface portions of the entrance of the ear canal of the user and to provide a seal limiting transmission of sound to the ear canal.

In accordance with a releasable lock feature of the invention, an end section **42** of the tubular portion **35** is of increased cross-sectional size to provide an external shoulder **43** in facing relation to the wall **32**. In assembly, a portion **44** of the compliant material of the device **38** is stretched over the end section **42** and then expands into the space between the shoulder **43** and the wall **32** as shown, so as to lock the device **38** and housing member **20** together while permitting disassembly when desired.

Custom earmolds or other types of coupling devices may be substituted for the illustrated device **38**, the subassembly of the housing member **20**, receiver **18** and other parts being thus usable with various types of coupling devices.

In accordance with further important features of the invention, the tubular portion **35** defines a passage **46** which has an outlet end portion **47** for propagation of acoustic energy into the earcanal of a user and an inlet end portion **48** in communication with the outlet port **20** of the receiver **18**. The outlet port **22** is preferably in the form of a tubular member which is fitted into the inlet end portion **47** of the passage **46** as shown. An acoustic damper **50** is fitted in the outlet end portion **47** of the passage **46** and, as illustrated, includes a cup-shaped screen member **51** secured in a cylindrical support member **52**. The outlet end portion **47** preferably has an enlarged diameter to provide a shoulder **53** operative to limit movement of the damper **50** toward the receiver **18** during assembly and to accurately fix its position. As shown, the portion of the screen member **51** which is transverse to the direction of sound transmission is in recessed relation to the end of the tubular housing portion **22** and the terminal end of the tubular housing portion is spaced a substantial distance from the terminal end of the coupling device, the result being that problems with wax accumulations on the screen are minimized. However, should such accumulations occur, a special removal tool as hereinafter described may be used to remove a clogged damper **50** which can then be replaced with a new damper.

With the construction as thus far described, the housing member **20** can be readily molded from plastic in one piece and it serves the functions of connecting to the outlet port of the receiver, supporting the damper, providing a sound passage and releasably connecting to a coupling device which may be of various possible types, such functions being performed with a high degree of accuracy and reliability.

Additional important features relate to the provision of a resilient support for the receiver **18** to minimize problems with noise and vibrations while facilitating assembly of the earphone. A piece of foam material **54** is provided having a generally rectangular form and a central opening **55** as depicted in FIG. **3**. In assembly, strain relief member **28** at the end of the cable **13** is installed in an opening in the end cap **29** and the conductors of the cable are connected directly or through the separate wires **25** and **26** as illustrated to the terminals **23** and **24** of the receiver **18**, being optionally extended through a resilient foam element **56**, as shown. Then the output port **22** of the receiver is inserted in the opening **55** of the piece **54** and the receiver is inserted into the chamber portion **19** and moved toward the wall **32** to press fit the output port **22** into the inlet end portion **48** of the passage **46**. During this assembly step, a portion **58** of the piece **54** is compressed between the end of the receiver **18** and the wall **32** and portions **59** and **60** of the piece **54** are folded back and compressed between the receiver and the outer wall **34** of the chamber portion **19**. As shown in the cross-sectional view of FIG. **4**, parts of the folded-back portions **59** and **60** extend along the sides of the receiver **18** as well as along the top and bottom of the receiver **18**. This assembly step is readily and quickly performed and results in a resilient support of the receiver **18** within the housing member **20** in a manner such as to minimize transmission of noise and vibrations thereto, functioning with a high degree of reliability. It also results in an acoustic seal between the output port **22** and the inlet end **48** of passage **46**. As a final assembly step, an epoxy or equivalent bonding means is used to secure the end cap **29** to the end of the housing member **20**.

FIG. **5** is a schematic diagram of the configuration of the junction unit **15** which connects the earphone cables **13** and **14** to the common cable **16** and which includes special electrical filters for enhancing the performance of the earphones **11** and **12**. One conductor **63** and one conductor **64** of the cables **13** and **14** are directly connected to a ground conductor **65** of the common cable **16**. A second conductor **67** of the cable **13**, a second conductor **68** of the cable **14**, and conductors **69** and **70** of cable **16** are respectively connected to pads **71**, **72**, **73** and **74** of a circuit board **76** which is formed with two circuits operative to increase the

signal applied to the receivers of the earphones **11** and **12** as a function of increasing frequency.

As shown, a capacitor **77** and a resistor **78** are connected in series between pads **71** and **73** while a resistor **80** is connected directly between pads **71** and **73**, in parallel with the series combination of capacitor **77** and resistor **78**. Similarly, a capacitor **81** and a resistor **82** are connected in series between pads **72** and **74** while a resistor **84** is connected directly between pads **71** and **73**. It will be apparent that at very low frequencies, when the capacitive reactance is high, the series impedances are determined primarily by the value of the resistors **80** and **84**. As the frequency increases, the series impedances are reduced, increasing the amplitudes of higher frequency components of the applied signals.

This electrical filtering operation is found to be highly desirable, permitting the use of an amount of acoustic damping sufficient to smooth out peaks in the acoustic responses of the earphones **11** and **12** while obtaining optimum frequency response characteristics. By way of example, the value of each of the resistors **78**, **80**, **82** and **84** may be 100 ohms and the value of each of the capacitors **77** and **81** may be 0.22 microfarads. The circuit board **76** and the parts thereon preferably have quite small dimensions. Each of the resistor and capacitor parts preferably has maximum dimensions of 0.150"×0.300"×0.100". These dimensions are desirable to obtain a compact junction unit and are such that if desired, as when a single earphone is to be used, the filter for each filter might be located within the earphone, e.g. between the receiver **18** and the end cap **29**. In a two earphone assembly such as the illustrated assembly **10**, however, it is generally preferable to locate the filters in the junction unit **15**.

FIG. **6** illustrates a tool usable for removal and replacement of a damper which has become clogged with wax or otherwise defective. A support rod **86** carries a threaded element **87** which has a pointed end **88** to be pushed into the screen of a defective damper while the rod **86** is rotated to engage the threads of the element **87** with a lip of the cylindrical support **52** of the damper **50**; the rod **86** being then retracted to withdraw the defective damper. Replacement dampers **89** may be contained in a chamber **90** within the support rod **86** and may be accessed by removal of an extension **91** of the rod **86**, the extension **91** having a reduced diameter threaded end portion **92** which is screwed into an internally threaded end portion of the replacement damper chamber **90**.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of this invention

What is claimed is:

1. An insert earphone comprising:

a unitary housing having a hollow body portion, the hollow body portion having an end wall and an open end disposed opposite the end wall and a hollow elongated tubular portion extending from the end wall;

an end cap;

a cable including a plurality of electrical conductors extending from an electrical audio signal source external to the housing, the cable being secured with the end cap, the end cap connected to cover the open end of the hollow body portion;

a receiver for transducing electrical energy received along the plurality of electrical conductors to sound energy, the receiver being supported within the hollow body portion of the housing and having a sound outlet port extending partially into the hollow elongated tubular portion of the housing in a closely conforming manner;

an insert formed from a resilient material, the insert being disposed between the receiver and at least one interior wall of the unitary housing to inhibit movement of the receiver within the hollow body portion and assisting to provide an acoustic seal between the hollow body portion and the elongated tubular portion;

a damper supported within the hollow elongated tubular portion of the housing at a position opposite the sound outlet port of the receiver, sound from the sound outlet port of the receiver being conducted to the damper by the hollow elongated tubular portion;

a resilient sealing member disposed over the hollow elongated tubular portion for sealing with an ear canal of a wearer;

the earphone extending into and substantially acoustically sealing the ear canal of the wearer when inserted, the damper and receiver response compensating for loss of external ear resonance and coupling resonance that otherwise would occur when the insert earphone is inserted into the ear canal of the wearer to thereby assist in providing a high fidelity response.

2. An insert earphone comprising:

a unitary housing having a hollow body portion, the hollow body portion having an end wall, at least one interior wall, and an open end disposed opposite the end wall, and a hollow elongated tubular portion extending from the end wall;

a receiver for transducing electrical energy received into sound energy, the receiver having a sound outlet port extending from an end thereof;

an insert formed of resilient material, the insert having a substantially central opening therein; and wherein, during assembly, the outlet port of the receiver is placed in the opening of the insert and the receiver and insert are inserted as a unit into the open end of the hollow body portion until the outlet port engages and extends partially into the hollow elongated tubular portion such that a portion of the insert is compressed between the end of the receiver and the end wall, and other portions of the insert are compressed between the receiver and the at least one interior wall, thereby mounting the receiver within the hollow body portion and assisting to provide an acoustic seal between the hollow body portion and the elongated tubular portion while providing for transmission of sound energy from the sound outlet port through the hollow elongated tubular portion into the ear canal of a wearer.

3. A high-fidelity insert earphone comprising:

a unitary housing having a hollow body portion, the hollow body portion having an end wall, and a hollow elongated tubular portion extending from the end wall;

a receiver for transducing electrical energy received into sound energy, the receiver having a sound outlet port extending from an end thereof, the sound outlet port having a first end and a second end; and

an insert formed from a resilient material, the insert being disposed between the end of the receiver and the end wall and flanking on the second end of the sound outlet port, the first end of the sound outlet port mating with, directly contacting a surface of, and extending into the hollow elongated tubular portion.

4. The high fidelity insert earphone of claim **3** wherein the insert mounts and inhibits movement of the receiver within the hollow body portion of the unitary housing.

5. The high-fidelity insert earphone of claim 3 further comprising a damper supported within the hollow elongated tubular portion of the housing at a position opposite the sound outlet port of the receiver, sound from the sound outlet port of the receiver being conducted to the damper by the hollow elongated tubular portion.

6. The high-fidelity insert earphone of claim 5 further comprising a resilient sealing member disposed over the hollow elongated tubular portion for sealing with an ear canal of a wearer.

7. The high fidelity insert earphone of claim 6 wherein the earphone extends into and substantially acoustically seals the ear canal of a wearer.

8. The high fidelity insert earphone of claim 7 wherein the earphone emulates a human ear's natural diffuse field response to sound energy received.

9. The high fidelity insert earphone of claim 6 wherein the resilient sealing member has a plurality of outwardly projecting flange portions of generally conical form and of progressively increasing diameters.

10. The high fidelity insert earphone of claim 9 wherein the earphone extends into and substantially acoustically seals the ear canal of a wearer.

11. The high fidelity insert earphone of claim 10 wherein the earphone emulates a human ear's natural diffuse field response to sound energy received.

12. An insert earphone comprising:

a receiver for transducing electrical energy received into sound energy, the receiver having a sound outlet port extending from an end thereof, the sound outlet port having a first end and a second end, the receiver having a radial dimension and at least one outer surface;

an insert formed from a resilient material, and having an uncompressed thickness; and

a unitary housing having a hollow body portion, the hollow body portion having at least one inner surface, a radial dimension, and an end wall, and a hollow elongated tubular portion extending from the end wall, the radial dimension of at least a portion of hollow body portion being less than the sum of the radial dimension of the receiver and the uncompressed thickness of the insert, and upon assembly, a first portion of the insert being disposed and compressed between the end of the receiver and the end wall, second and third portions of the insert being disposed and compressed between the at least one outer surface of the receiver and the at least one inner surface of the hollow body portion, the first end of the sound outlet port directly contacting a surface of the hollow elongated tubular portion and extending into the hollow elongated tubular portion, and only the second end of the sound outlet port being flanked by the insert, the insert thereby mounting the receiver in the hollow body portion and assisting to provide an acoustic seal between the hollow body portion and the elongated tubular portion of the housing.

13. A method of assembling an insert earphone comprising a receiver having a sound outlet port extending from an end thereof, a unitary housing having a hollow body portion, the hollow body portion having an end wall and an open end disposed opposite the end wall, and a hollow elongated tubular portion, and a resilient insert having a substantially central opening therein, the method comprising the steps of:

placing the sound outlet port of the receiver through the opening of the resilient insert;

inserting the receiver, sound outlet port first, and the resilient insert as a unit into the open end of the hollow body portion;

moving the inserted receiver toward the end wall such that first and second portions of the resilient insert are folded back in a direction toward the open end and compressed between the receiver and at least one inner surface of the hollow body portion; and

matings engaging the sound outlet port of the receiver with the hollow elongated tubular portion such that a third portion of the resilient insert is compressed between the end of the receiver and the end wall.

14. The method of claim 13 further comprising the step of operatively coupling an electrical energy source to the receiver.

15. The method of claim 14 wherein the insert earphone further comprises an end cap, and further comprising the step of securing the end cap to the open end of the hollow body portion.

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